Appendix F

Methodology for Calculating Allowable Bacteria Loads and Load Reductions

This appendix describes the methodology for calculating and allocating the allowable bacteria loads to Tecolote Creek. Part I discusses the wet weather analysis from which interim TMDLs were derived. The wet weather interim analysis used the water contact recreational (REC-1) beneficial use single sample maximum water quality objectives (WQOs) for total coliform (TC), fecal coliform (FC), and *Enterococcus* (ENT) as interim numeric targets and incorporated the reference system approach discussed in section 3.1 of the Technical Report. Part II discusses the wet weather analysis from which final TMDLs were derived. This analysis used REC-1 single sample maximum WQOs for TC, FC, and ENT as final numeric targets for the length of Tecolote Creek, and did not incorporate the reference system approach. Part III discusses the dry weather analyses and the use of numeric targets. Part IV provides estimated bacteria contributions from each land use type based on the wet-weather watershed model results. Part V discussed the methodology used to calculate load and wasteload reductions.

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I. Calculation of Allowable Loads Using Interim Numeric Targets for Wet Weather Analysis

For the interim wet weather TMDL analysis, allowable loads were calculated using the Loading Simulation Program in C++ (LSPC) watershed model and an exceedance frequency. The exceedance frequency was used to calculate an allowable exceedance load. The purpose of the exceedance frequency is to account for the natural, and largely uncontrollable sources of bacteria (e.g., bird and wildlife feces) in the wet weather loads generated in the watersheds, which can, by themselves, cause exceedances of the WQOs. The exceedance frequency is determined by using a reference system approach. The reference system approach allows exceedances of the single sample WQOs for REC-1 beneficial uses.

For the interim wet weather TMDL analysis, the LSPC model output was used to produce load-duration curves[1] for the critical wet weather condition using REC-1 WQOs and the reference system approach. The LSPC model was run for a "critical wet weather condition." The critical wet weather condition was selected by reviewing data from multiple rainfall gages in the San Diego Region over a recent 15-year period (1990 through 2005). The wettest year, 1993, was selected as the critical wet period for assessment of extreme wet weather loading conditions. Statistically, 1993 corresponds to the 93rd percentile of annual rainfalls for those 15 years measured at Lindbergh Field.

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[1] Load-duration curves display modeled daily loads ranked according to the magnitude of the modeled average daily flow associated with the load for a specific location. The height of the bars corresponds to the magnitude of the bacteria load (billion MPN). Section 7.1.5 of the Technical Report shows interim and final load-duration curves for Tecolote Creek for each type of bacteria.

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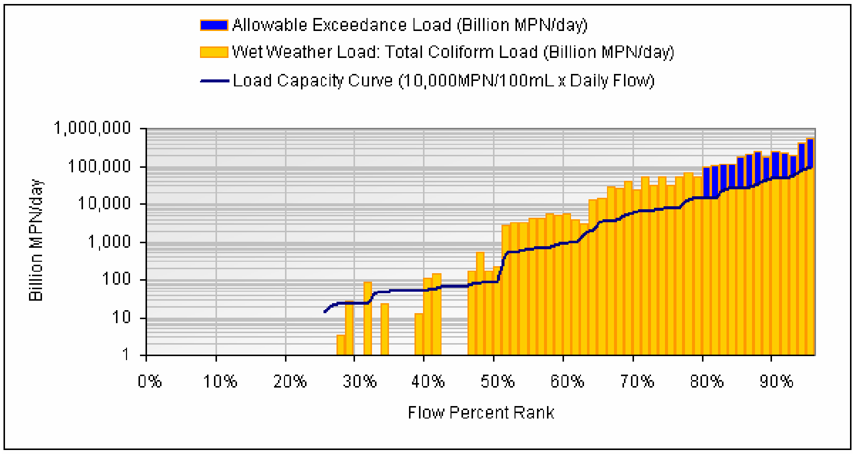
The load-duration curves for the interim wet weather TMDL calculations were used to calculate the allowable loads, allowable exceedance loads based on the reference system approach, and the non-allowable exceedance loads. The calculations for the allowable loads, allowable exceedance loads, interim TMDLs, and the non-allowable exceedance loads are described below.



Total Coliform Loading Summary	Value	Units
Number of Exceedence Days (Bars with Segment above LC Curve)	44	None
Allowable Wet Day Exceedances (Bars with Blue Segments)	13	None
Excess Wet Day Exceedances	31	None
Total Load for Existing Condition (All Bar Segments)	3,400,693	Billion MPN/Year
Allowable Load (Bar Segments under LC Curve)	627,552	Billion MPN/Year
Allowable Exceedance Load (Blue Bar Segments)	2,348,125	Billion MPN/Year
Exceedance Load (Yellow Bar Segments above LC Curve)	425,531	Billion MPN/Year
Required Annual Load Reduction	12.5%	Percentage

Figure F-1: Total Coliform Load-Duration Curve and Interim TMDL for Tecolote Creek Watershed (REC-1)

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1. Quantify Total Existing Bacteria Loads

The LSPC model described in Appendix E was used to predict bacteria loading to Tecolote Creek. Model-predicted loads were used to construct load-duration curves for each of the three indicator bacteria. A sample load-duration curve is shown in Figure F-1. This bar graph, or load-duration curve, shows model-calculated total coliform loads at the mouth of Tecolote Creek (identified as subwatershed number 1700) using the REC-1 WQOs.

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The load-duration curve shows model-predicted bacteria loads for the critical wet weather condition. Load-duration curves are bar graphs that rank the modeled flows into percentiles, or groups arranged in increasing orders of magnitude. The height of the bars indicates the number of total coliform colonies corresponding to the flow volume on a given day. The summation of all the bar segments represents the total existing annual bacteria load for wet weather in the critical wet weather year.

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2. Quantify Allowable Load
The dark line running across the bar graph (referred to as the “numeric target line” or “load capacity curve”) in Figure F-1 represents the total maximum bacteria load that would not result in an exceedance of the numeric target for the flow volume on that day. In this case, the numeric target is the REC-1 WQO for TC. The load capacity curve is calculated by multiplying the numeric target by the total flow volume for each day. So, if the daily flow volume increases, the target daily load will increase; but the numeric target stays constant.

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The summation of the bar segments below the numeric target line represents the loading capacity of the waterbody on an annual basis that will not cause numeric targets to be exceeded.

3. Quantify Interim Allowable Exceedance Load
For interim wet weather TMDL calculations, an exceedance frequency is used to account for the natural, and largely uncontrollable sources of bacteria (e.g., bird and wildlife feces) in the wet weather loads generated in the watersheds. The exceedance frequency is determined by using the reference system approach. Twenty-two percent is the frequency of exceedance of the REC-1 single sample maximum WQO measured in a reference system in Los Angeles County, which is also being applied to the Tecolote Creek watershed.

For the Tecolote Creek watershed, the number of wet days in the critical wet weather year (1993) was determined to be 57 days (Technical Report, section 7.1.2). The number of days that exceedances of numeric targets are allowed was obtained by multiplying the number of wet days by the exceedance frequency (Technical Report, section 7.1.3). For the Tecolote Creek watershed, the number of allowable exceedance days is:

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57 Wet Days * 0.22 = 13 Allowable Exceedance Days

The allowable exceedance load was calculated by summing the loads associated with the allowable exceedance days. The days with the highest loads were chosen as the allowable exceedance days because the highest loads in most of the watersheds correspond to open space land uses where bacteria loads are generated from natural sources. The allowable exceedance loads are shown as the blue bar segments on the load-duration curves. Although the blue bars are in exceedance of the numeric targets (magnitude is above the load capacity curve), these loads are considered uncontrollable, and not likely to be associated with human pathogens.

4. Calculate Interim Wet Weather TMDL
The interim wet weather TMDL is the sum of the allowable load and allowable exceedance load. The allowable loads were calculated using the numeric target and are represented on the load-duration curve as the sum of the bar segments below the load capacity curve. The allowable exceedance loads take into account the natural, and

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largely uncontrollable sources of bacteria (e.g., bird and wildlife feces), which is represented by the blue bar segments above the load capacity curve. The sum of the bar segments below the load capacity curve and the blue segments above the load capacity curve are equivalent to the interim wet weather TMDL on an annual basis.

The remaining orange bar segments above the load capacity curve represent exceedance loads. These exceedance loads must be reduced to meet the interim wet weather TMDL.

5. <u>Calculate Required Percent Reduction for Interim TMDL</u>
The percent reduction required for bacteria in the Tecolote Creek watershed to meet the interim wet weather TMDLs were calculated using the following equation (Note that all loads are annual loads):

$$\text{Percent Reduction} = \frac{(\text{Total Existing Load} - \text{Allowable Load} - \text{Allowable Exceedance Load})}{\text{Total Existing Load}}$$

The Total Existing Load, Allowable Load, and Allowable Exceedance Load values are obtained directly from the tables associated with the load duration curves. Using the values from Figure F-1, the percent reduction is:

$$\text{Percent Reduction} = \frac{(3{,}400{,}693 \text{ Billion MPN/Yr} - 627{,}552 \text{ Billion MPN/Yr} - 2{,}384{,}125 \text{ Billion MPN/Yr})}{3{,}400{,}693 \text{ Billion MPN/Yr}}$$

$$\begin{aligned}\text{Percent Reduction} &= 0.125 \times 100\% \\ &= 12.5\%\end{aligned}$$

In this case, the required interim wet weather reduction for TC in the Tecolote Creek watershed in order to meet the interim numeric targets based on the REC-1 WQO with a reference system approach is 12.5 percent.

II. Calculation of Allowable Loads Using Final Numeric Targets for Wet Weather Analysis

The methodology for calculating the final allowable loads and load reductions is similar to the methodology for calculating interim allowable loads. The difference is that with calculation of the final allowable loads, the reference system approach is not used to account for loads due to natural and largely uncontrollable sources of bacteria (e.g., bird and wildlife feces) in the wet weather loads generated in the watersheds. In other words, the allowable exceedance load (represented by the blue-colored bars in Figure F-1) are not included as part of the final wet weather TMDL calculations.

For the length of Tecolote Creek, the REC-1 single sample maximum WQOs for TC, FC, and ENT were selected as numeric targets for the length of Tecolote Creek.

Figure F-2 shows the load-duration curve for TC for the Tecolote Creek watershed, using the REC-1 WQO as the numeric target.

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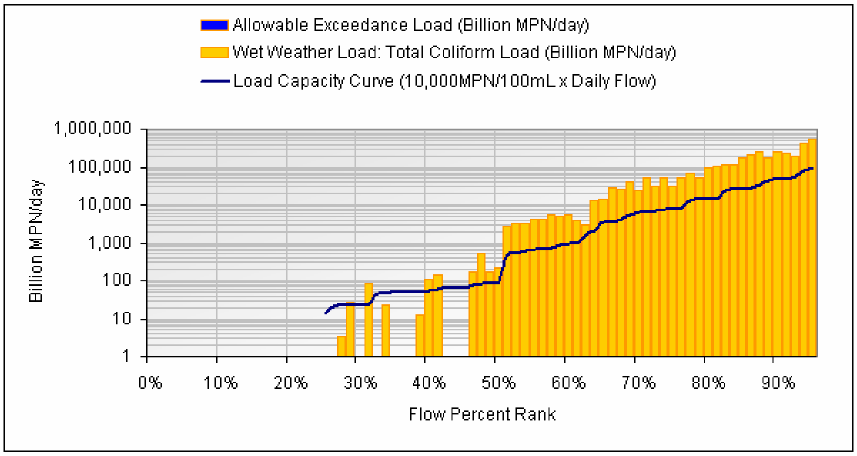

Total Coliform Loading Summary	Value	Units
Total Load for Existing Condition (All Bar Segments)	3,400,693	Billion MPN/Year
Allowable Load (Bar Segments under LC Curve)	627,552	Billion MPN/Year
Exceedance Load (Yellow Bar Segments above LC Curve)	2,773,141	Billion MPN/Year
Required Annual Load Reduction	81.5%	Percentage

Figure F-2: Total Coliform Load-Duration Curve and Interim TMDL for Tecolote Creek Watershed (REC-1)

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A comparison of Figures F-1 and F-2 reveal that the only difference in the graphs is that there are no allowable exceedance loads (represented by blue bar segments) in Figure F-2. In contrast to the discussion in Part I, the sum of all the bar segments above the load capacity curve, whether or not they are caused by natural sources, are considered exceedance loads and must be reduced. The allowable load is now only the sum of the bar segments below the numeric target line.

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The load-duration curves for the final wet weather TMDL calculations were used to calculate the allowable loads, and the non-allowable exceedance loads. The calculations for the allowable loads, final TMDLs, and the non-allowable exceedance loads are described below.

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1. <u>Quantify Total Existing Bacteria Loads</u>
The total existing bacteria loads in the final load-duration curves are calculated in the same manner as in the interim load-duration curves. The summation of all the bar segments represents the total existing annual bacteria load for wet weather in the critical wet weather year.

2. <u>Quantify Allowable Load</u>
As with the interim load-duration curves, the summation of the bar segments below the numeric target line represents the loading capacity of the waterbody on an annual basis that will not cause numeric targets to be exceeded.

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3. Calculate Final Wet Weather TMDL

The sum of the bar segments below the load capacity curve are equivalent to the final wet weather TMDL on an annual basis.

The orange bar segments above the load capacity curve represent exceedance loads. These exceedance loads must be reduced to meet the final wet weather TMDL.

4. Calculate Required Percent Reduction for Final TMDL

The percent reduction required for bacteria in the Tecolote Creek watershed to meet the final wet weather TMDLs were calculated using the following equation (Note that all loads are annual loads):

$$\text{Percent Reduction} = \frac{\text{(Total Existing Load – Allowable Load)}}{\text{Total Existing Load}}$$

The Total Existing Load, Allowable Load, and Allowable Exceedance Load values are obtained directly from the tables associated with the load duration curves. Using the values from Figure F-2, the percent reduction is:

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$$\text{Percent Reduction} = \frac{\text{(3,400,693 Billion MPN/Yr – 627,552 Billion MPN/Yr)}}{\text{3,400,693 Billion MPN/Yr}}$$

$$\begin{aligned}\text{Percent Reduction} &= 0.815 \times 100\% \\ &= 81.5\%\end{aligned}$$

In this case, the required final wet weather reduction for TC in the Tecolote Creek watershed in order to meet the final numeric targets based on the REC-1 WQO is 81.5 percent.

III. Calculation of Allowable Loads Using Numeric Targets for Dry Weather

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Because the density of bacteria in receiving water during dry weather is extremely variable in nature, a separate approach was needed. Dry weather days were selected based on the criterion that less than 0.2 inch of rainfall was observed on each of the previous 3 days. An approach was developed that relied on detailed analysis of available data to better identify and characterize sources.

Data analyses were used to estimate average bacteria loads during dry weather conditions (based on flow-weighted average concentrations), resulting in a constant dry weather bacteria load from the watershed. This existing load is representative of the average flow and bacteria loading conditions resulting from various urban land use practices (e.g., runoff from lawn irrigation or sidewalk washing). Because dry weather loading was estimated using an average flow, there was no critical dry period identified. The dry weather TMDL was calculated by multiplying the average annual dry weather flow by the appropriate numeric target.

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Unlike the wet weather model, the dry weather model does not use the reference system approach. This is because available data show that exceedances of WQOs in local reference systems during dry weather conditions are uncommon (see Technical Report, section 3.2). Furthermore, reference systems do not generate significant dry weather bacteria loads because flows are minimal. During dry weather, flow, and hence bacteria loads, are largely generated by urban runoff, which is not a product of a reference system.

The Total Load for Existing Condition and Allowable Load values are obtained by multiplying the annual dry weather flow by the observed flow-weighted average concentration and numeric target, respectively. Numeric targets for dry weather TMDLs were calculated using the REC-1 geometric mean WQOs. An example calculation of an existing load and dry weather TMDL is shown below for TC bacteria in the Tecolote Creek watershed.

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	Average Dry Weather Flow (cfs)	x	Bacteria Concentration (MPN/100mL)[a]	=	Daily Load (MPN/day)	=	Annual Dry Weather Load (Billion MPN/Yr)[b]
Existing Load	0.36	x	46,550[c]	=	410,039,357,716	=	126,292
TMDL	0.36	x	1,000[d]	=	8,808,652,800	=	2,713

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[a]This value must be multiplied by 24,468,480 (86,400 sec/day x 28.32 L/ft^3 x 1000mL/L ÷ 100mL) to convert to MPN/day.
[b]Based on 308 dry days in 1993 (365 days – 57 wet days).
[c]Based on the observed flow-weighted average concentration at water quality monitoring stations located throughout the Tecolote Creek watershed.
[d]Based on REC-1 geometric mean WQO.

To account for uncertainty in the analyses, a 10 percent explicit margin of safety (MOS) was included in the dry weather TMDL analysis (see Technical Report, section 7.2.4). This MOS was calculated by multiplying the dry weather TMDL by 10 percent. The resulting value was then subtracted from the dry weather TMDL to determine the allowable load (Allowable Load = 2,713 – [2,713 * 0.10] = 2,442 Billion MPN/Yr).

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The following formula is used to calculate the percent reduction:

$$\text{Percent Reduction} = \frac{(\text{Total Existing Load} - \text{Allowable Load})}{\text{Total Existing Load}}$$

Using the values from the total coliform example above, the required dry weather reduction for total coliform in the Tecolote Creek watershed to meet numeric targets is 98.1 percent.

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$$\text{Percent Reduction} = \frac{(126{,}292 \text{ Billion MPN/Yr} - 2{,}442 \text{ Billion MPN/Yr})}{126{,}292 \text{ Billion MPN/Yr}}$$

$$\begin{aligned}\text{Percent Reduction} &= 0.981 \times 100\% \\ &= 98.1\%\end{aligned}$$

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IV. Distribution of Bacteria Loads Generated by Different Land Uses

The sum of all bars in the wet weather load-duration curves provide an estimate of the total load expected during the critical condition (rainfall conditions documented in 1993). The LSPC watershed model was used to calculate the contribution from each land use type to the TMDL load. Land uses were divided into 13 land use categories (see Appendix E for discussion). For the Tecolote Creek watershed, for each type of indicator bacteria, model results were used to determine the load distribution by land use category. These distributions were expressed as a percent of the total load, and are displayed in pie charts in Figures E-3 through E-5 for TC, FC, and ENT bacteria, respectively.

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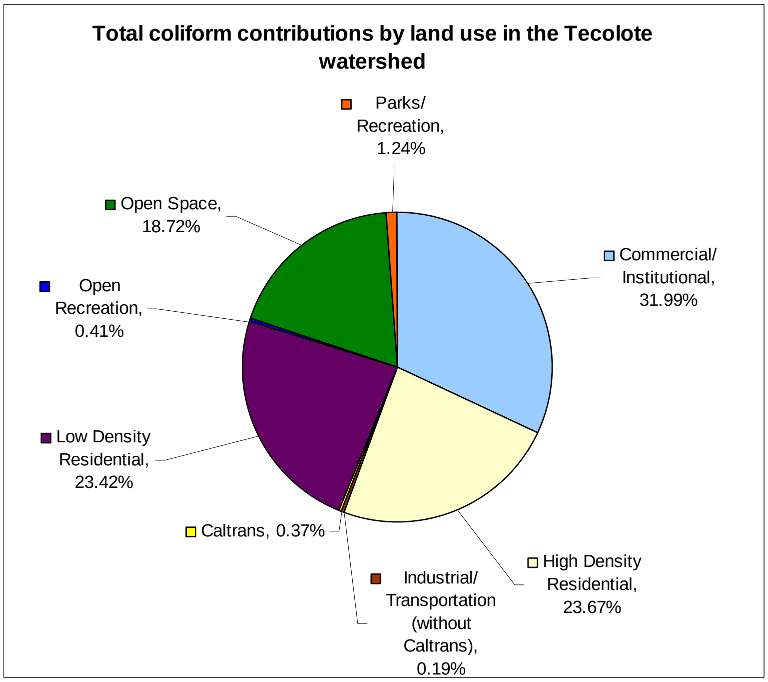

Figure E-3: Total coliform contributions by land use in the Tecolote watershed

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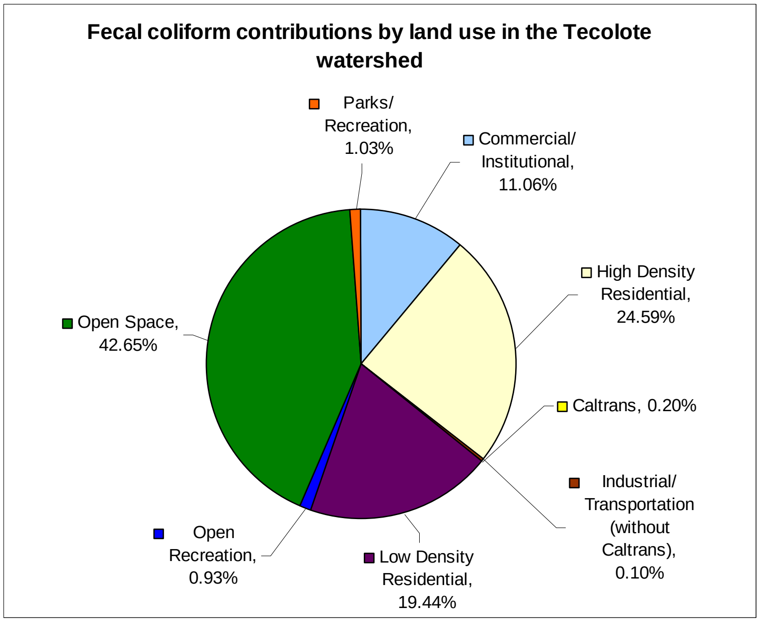

Figure F-4: Total coliform contributions by land use in the Tecolote watershed

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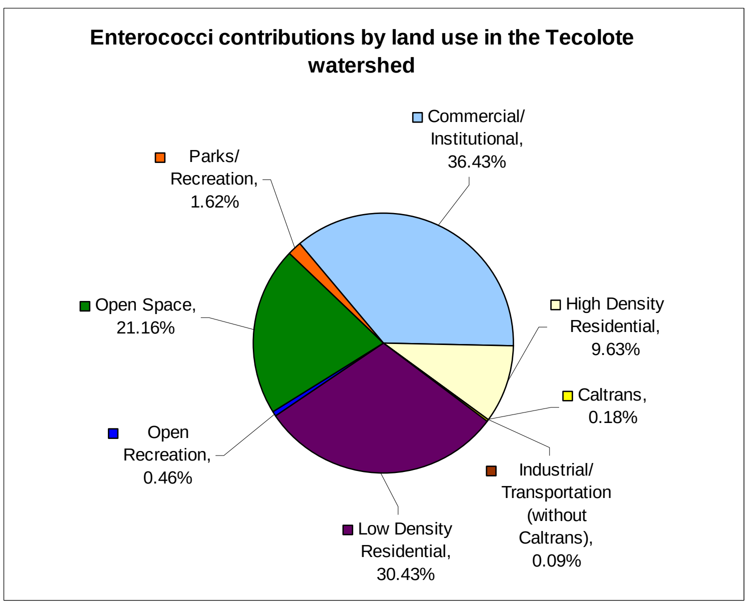

Figure F-5: Enterococcus contributions by land use in the Tecolote watershed

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These percentages can be used to calculate the existing bacteria load contribution according to the land use categories. This is done by multiplying the land use contribution percentage by the total existing load calculated in the load-duration curves (see Tables F-1 through F-3).

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Table F-1: Total Coliform Existing Wet Weather Bacteria Load Contributions by Land Use in the Tecolote Creek Watershed

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Land Use	Source Type	Land Use Load Percentage	Land Use Existing Load (Billion MPN/Yr)
Low Density Residential	Point	23.42%	796,395
High Density Residential	Point	23.67%	805,066
Commercial/Institutional	Point	31.99%	1,087,753
Industrial/Transportation	Point	0.19%	6,340
Caltrans	Point	0.37%	12,459
Parks and Recreation	Point	1.24%	42,276
Military	Point	0.00%	43
Open Recreation	Nonpoint	0.41%	13,912
Open Space	Nonpoint	18.72%	636,450
Total		**100.00%**	**3,400,693**

Table F-2: Fecal Coliform Existing Wet Weather Bacteria Load Contributions by Land Use in the Tecolote Creek Watershed

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Land Use	Source Type	Land Use Load Percentage	Land Use Existing Load (Billion MPN/Yr)
Low Density Residential	Point	19.44%	27,132
High Density Residential	Point	24.59%	34,322
Commercial/Institutional	Point	11.06%	15,432
Industrial/Transportation	Point	0.10%	144
Caltrans	Point	0.20%	283
Parks and Recreation	Point	1.03%	1,441
Military	Point	0.00%	4
Open Recreation	Nonpoint	0.93%	1,300
Open Space	Nonpoint	42.65%	59,527
Total		**100.00%**	**139,585**

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Table F-3: Enterococcus Existing Wet Weather Bacteria Load Contributions by Land Use in the Tecolote Creek Watershed

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Land Use	Source Type	Land Use Load Percentage	Land Use Existing Load (Billion MPN/Yr)
Low Density Residential	Point	30.43%	99,659
High Density Residential	Point	9.63%	31,543
Commercial/Institutional	Point	36.43%	119,334
Industrial/Transportation	Point	0.09%	298
Caltrans	Point	0.18%	585
Parks and Recreation	Point	1.62%	5,298
Military	Point	0.00%	5
Open Recreation	Nonpoint	0.46%	1,515
Open Space	Nonpoint	21.16%	69,308
Total		**100.00%**	**327,545**

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V. Calculation of Load and Wasteload Reductions

Federal regulations [40 CFR 130.7] require TMDLs to include individual WLAs for each point source and LAs for each nonpoint source. The only point sources identified to affect Tecolote Creek were MS4s and Caltrans, although other point sources of bacteria may exist. USEPA's permitting regulations require municipalities to obtain NPDES requirements for all stormwater discharges from MS4s. The existing loads estimated were solely the result of watershed runoff, not other types of point sources. WLAs were assigned to municipalities (the City of San Diego) and Caltrans.

LAs were assigned to non-controllable nonpoint sources. Non-controllable nonpoint sources can include bacteria generated in open recreation and open space land uses. Controllable nonpoint sources can include discharges from agricultural facilities and livestock operations which are quantified by the agriculture, dairy/intensive livestock, and horse ranches land use categories. The only controllable nonpoint source identified in the Tecolote Creek watershed is Mesa College's animal facility, which is a negligible percent of the total sources of bacteria for Tecolote Creek.

The TMDLs were distributed as follows:

$$TMDL = WLA_{MS4s} + WLA_{Caltrans} + LA_{Open\ Space/Rec}$$

where $TMDL$ = Total Maximum Daily Load for entire watershed
WLA_{MS4s} = Wasteload allocation for owners/operators of MS4s
$WLA_{Caltrans}$ = Wasteload allocation for Caltrans
$LA_{OpenSpace/Rec}$ = Load allocation for uncontrollable sources of bacteria

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Since loads from Open Space and Open Recreation land uses are uncontrollable, the LAs for this category cannot be lower than the existing loads. Therefore the LAs for this category are the same as the existing loads generated by uncontrollable sources, as calculated above in Tables F-1 through F-3 of Part IV, and cannot be reduced.

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Similarly, for Caltrans, the WLAs are identical to the existing loads generated by Caltrans in each watershed. However, the reasoning for this determination is different than the reasoning described for loading from uncontrollable sources. Inspection of Tables F-1 through F-3 indicate that loading from the Industrial/Transportation land use is approximately 1 percent or less of the total existing load in all watersheds. The Caltrans WLA is an insignificant source of bacteria compared to other controllable sources. Therefore, the San Diego Water Board shall not impose stricter regulation than what is already in place.

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The remaining portions of the TMDL are allocated to the MS4s. Although allocations are distributed to the identified dischargers of bacteria, this does not imply that other potential sources do not exist. Any potential sources in the watersheds, such as publicly owned treatment works, not receiving an explicit allocation as described above is allowed a zero discharge of bacteria to Tecolote Creek.

The load and wasteload reductions are calculated using the following methodology:

1. Calculate the Existing Load Contribution for the Allocation Categories (Open Spaces, Caltrans, and MS4s)

Continuing the example using the load-duration curve from Figure F-1, the existing load contribution for open spaces, Caltrans and MS4s are presented in Table F-4.

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Table F-4: Total Coliform Allocation Category Existing Load in the Tecolote Creek Watershed

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Land Use	Land Use Load Percentage	Land Use Existing Load (Billion MPN/Yr)	Allocation Category	Allocation Category Existing Load (Billion MPN/Yr)
Low Density Residential	23.42%	796,395	MS4	2,737,873
High Density Residential	23.67%	805,066		
Commercial/Institutional	31.99%	1,087,753		
Industrial/Transportation	0.19%	6,340		
Parks and Recreation	1.24%	42,276		
Military	0.00%	43		
Caltrans	0.37%	12,459	Caltrans	12,459
Open Recreation	0.41%	13,912	Open Spaces	650,362
Open Space	18.72%	636,450		
Total	**100.00%**	**3,400,693**		**3,400,693**

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2. Calculate the TMDL, LAs, and WLAs

The interim wet weather TMDL is the sum of the allowable load and the allowable exceedance load. For TC, the interim wet weather TMDL is equal to the sum of 627,552 Billion MPN/Yr and 2,384,125 Billion MPN/Yr, or 2,975,678 Billion MPN/Yr. The LA and WLAs are presented in Table F-5.

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Table F-5: Total Coliform TMDL, LA, and WLAs for the Tecolote Creek Watershed

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Allocation Category	Bacteria Load Allocation (Billion MPN/Yr)	Comments
TMDL	2,975,678	Allowable Load + Allowable Exceedance Load
$LA_{Open\ Spaces}$	650,362	Open Recreation & Open Space Land Use Existing Load, Uncontrollable
$WLA_{Caltrans}$	12,459	No reduction required
WLA_{MS4s}	2,312,857	WLA (MS4s) = TMDL – $LA_{Open\ Spaces}$ – $WLA_{Caltrans}$

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For dry weather, the TMDLs were allocated solely to MS4s because urban runoff is overwhelmingly the main source of bacteria loading during dry weather conditions. Allocations for nonpoint sources were unnecessary since land uses associated with these sources generally do not generate runoff to receiving water during dry weather conditions. Additionally, dry weather loads from Caltrans highways were assumed to be insignificant because during dry periods there is no significant urban runoff from Caltrans owned roadway surfaces.

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3. Calculate the Load Reductions

Because allocations for open spaces and Caltrans do not require reduction, only the MS4s allocations are required to reduce their existing loads to meet the TMDL. Therefore, the percent wasteload reduction required by MS4s is calculated using the following equation:

$$\text{Percent Reduction by MS4s} = \frac{(\text{MS4 Allocation Category Load} - WLA_{MS4s})}{\text{MS4 Allocation Category Load}}$$

For this example, the MS4s Allocation Category Load value is from Table F-4 and MS4s WLA value is from Table F-5. Using these values, the percent reduction is:

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$$\text{Percent Reduction by MS4s} = \frac{(2{,}737{,}873 \text{ Billion MPN/Yr} - 2{,}312{,}857 \text{ Billion MPN/Yr})}{2{,}737{,}873 \text{ Billion MPN/Yr}}$$

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$$\text{Percent Reduction by MS4s} = 0.155 \times 100\%$$
$$= 15.5\%$$

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The same process is used for the wet weather and dry weather load reduction calculations. However, if the sum of the open space LA and the Caltrans WLA is greater than or equal to the TMDL, then the MS4s WLA is zero.

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